Sino Swearingen
AIRCRAFT CORPORATION

Ice Shapes Flight Test Program

John Siemens
Sr. Manager Flight Operations
Chief Test Pilot

Presented by: Mario Asselin, Manager Flight Sciences

SJ30-2

- The SJ30-2 is a high speed long range business jet designed for single pilot operations with up to 6 passengers.
- It has a high speed wing (30° sweep) and an M_{MO} of Mach 0.83;
- It has a design range of 2500nm;
  - LAX-JFK: 2200 nm
  - YQX-GVA: 2400 nm
- It is equipped with large fowler flaps and leading edge slats for low speed capability;
  - Stall identification speed at max landing weight of 91 KCAS.
  - Typical V_{REF} of 99 KIAS

Icing Program

- System Development
- Dry Air Tests
- Climatic Chamber (Eglin AFB)
- Natural Icing Tests
- Ice Shapes Analysis
- Ice Shapes
- Ice Shapes Testing

SJ30 Ice Protection

Electric Systems

- **Pitot/Static Systems**
- **AOA / Stall Warning**
- **Temperature Probes**
- **Ice Detection**
- **Windshields**

Bleed Air

- **Wing LE/Slats**
- **Engine Inlet**

Pneumatic Tail Deice Boots

Vertical Tail - Unprotected

Ice Shapes Program

Multi-Phased Program

1. Initial Ice Shapes Tests (Dec 2004 – Mar 2005)
    - Computer generated shapes
2. Completion of Company Tests (Jan 2006)
    - Refined shapes based on company natural icing results
3. FAA Certification Tests (Feb 2006)

Sino Swearingen AIRCRAFT CORPORATION

Ice Shapes Program

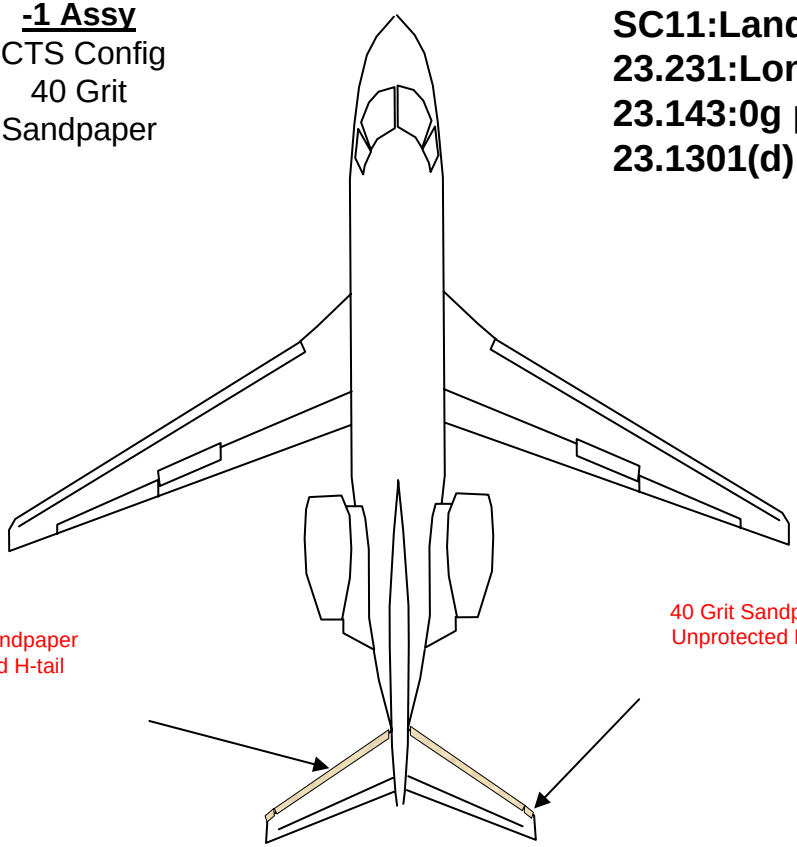
Ice Shape Configuration Matrix

	-1 Assy	**-2 Assy**	**-3 Assy**	**-4 Assy**	**-5 Assy**
	Tail Plane Stall Trace	Delayed Activation	System Operational	Wing Failure	De-ice Boot Failure
Wing Tips L,R		2 min	45 min	45 min	45 min
Unprotected Vertical		2 min	45 min	45 min	45 min
Unprotected Horizontal		2 min	45 min	45 min	45 min
Protected Tail L Horiz	40 grit sandpaper	2 min	*1 min	*1 min	22.5 min
Protected Tail R Horiz	40 grit sandpaper	2 min	*1 min	*1 min	22.5 min
Protected Wing L&R		2 min		9 min	
Engine Pylon		2 min	45 min	45 min	45 min
Raydome		2 min	45 min	45 min	45 min

-1 Ice Shapes

-1 Assy
ICTS Config
40 Grit
Sandpaper

SC11:Simulated Approach, Landing, and Go-Around
SC11:Landing Demonstration
23.231:Longitudinal Ground Handling, F31GD
23.143:0g pushover (Tail Plane Stall)
23.1301(d):Qualitative Autopilot Operations



40 Grit Sandpaper
Protected H-tail

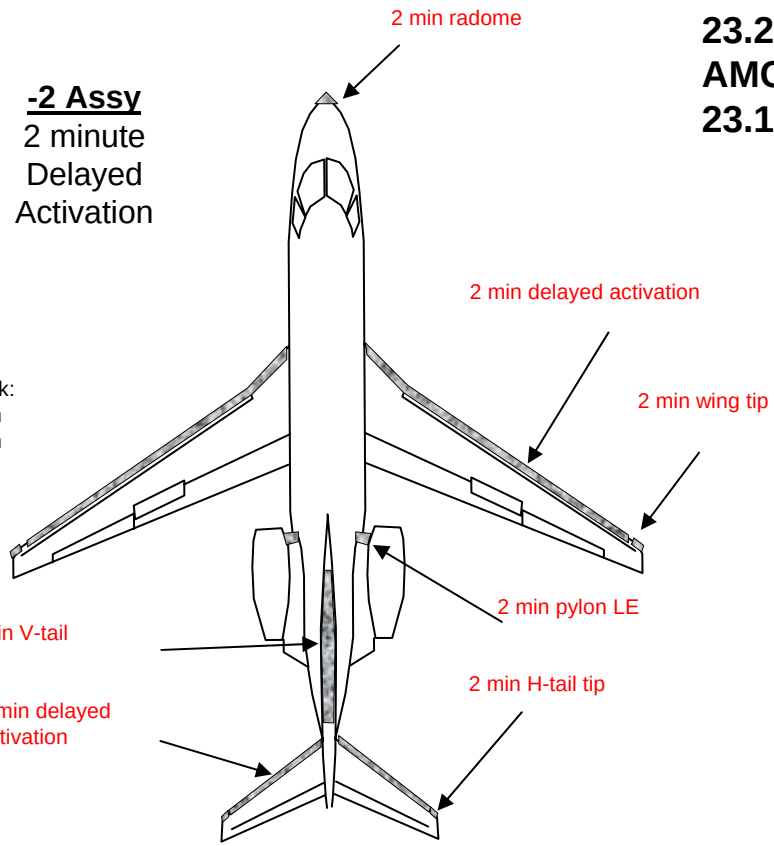
40 Grit Sandpaper
Unprotected H-tail

Sino Swearingen
AIRCRAFT CORPORATION

-2 Ice Shapes

SC18:Stall Demonstration
SC9/23.69:OEI Climb
SC11:Simulated Approach, Landing, and Go-Around
SC11:Landing Demonstration
23.231:Longitudinal Ground Handling, F31GD
AMC 143-F1:Maneuver Margins
23.1301(d):Qualitative Autopilot Operations

-2 Assy
2 minute
Delayed
Activation

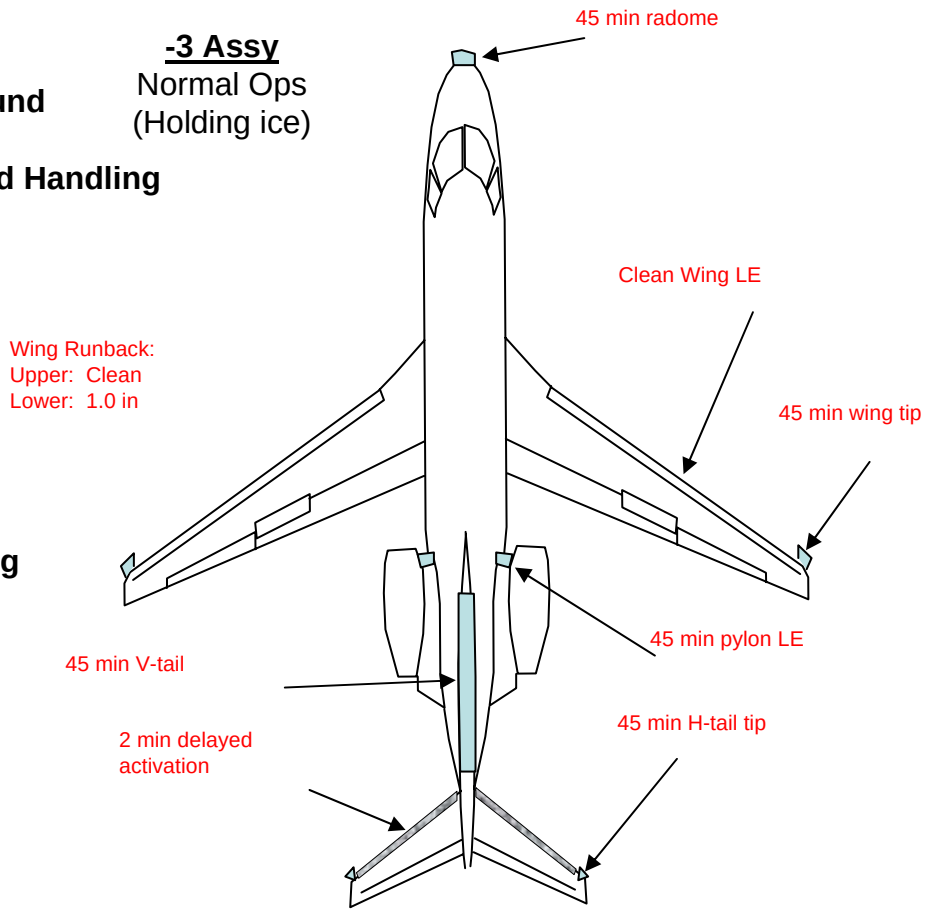


Wing Runback:
Upper: Clean
Lower: Clean

-3 Ice Shapes

SC13: Stall Speed
SC10/23.66/SC12:Check Climbs
SC11: Simulated Approach, Landing, and Go-Around
SC11: Landing Demonstration
23.231/23.233:Longitudinal and Directional Ground Handling
23.143: 0g pushovers
23.145: Longitudinal Control
23.147: Directional and Lateral Control
23.149: Minimum Control Speed
23.157: Rate of Roll
SC14: Trim
SC15/SC16: Static Longitudinal Stability
SC17: Static Directional and Lateral Stability
23.181: Dutch Roll
SC18/SC19/SC20:Stall Characteristics and Warning
AMC 143-F1:Maneuver Margins
SC21: Vibration and Buffet
23.1301(d): Qualitative Autopilot Operations

-3 Assy
Normal Ops
(Holding ice)

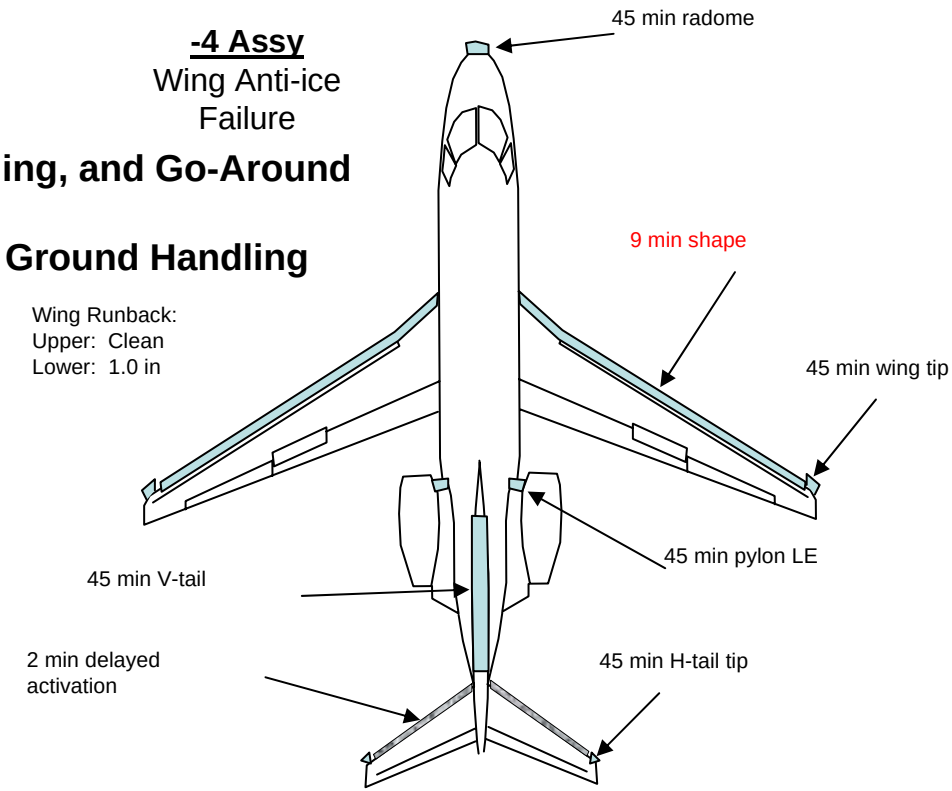


Sino Swearingen
AIRCRAFT CORPORATION

-3 Ice Shapes

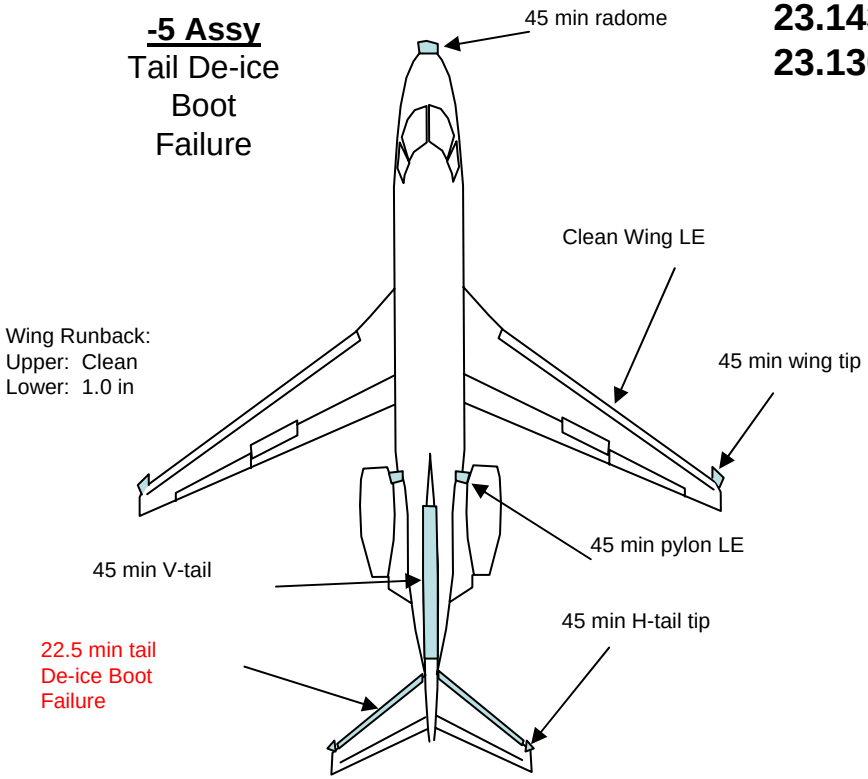
-4 Ice Shapes

SC18: Stall Demonstration
SC11: Simulated Approach, Landing, and Go-Around
SC11: Landing Demonstration
23.231/23.233:Longitudinal and Directional Ground Handling



-5 Ice Shapes

SC11:Simulated Approach, Landing, and Go-Around
SC11:Landing Demonstration
23.231/23.233:Longitudinal and Directional Ground Handling
23.143: 0.5 g pushovers
23.1301(d):Qualitative Autopilot Operations



Sino Swearingen
AIRCRAFT CORPORATION

Ice Shapes Buildup

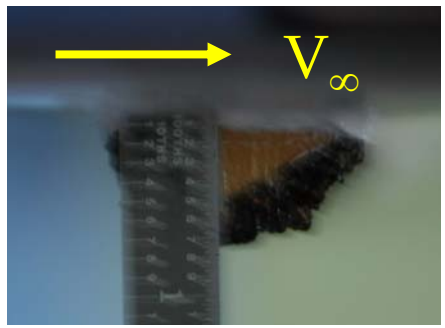
1. Least critical to most critical shapes
2. Inboard to outboard (root to tip symmetrically)
    a) 3 pieces on each side of horizontal
    b) 3 pieces on vertical tail
    c) 5 pieces on each wing
3. Lower surface runback
4. Upper surface runback

- Taxi runs to test controllability prior to flight
- Raise the landing gear at positive rate of climb
- No change in flap configuration until 10,000 ft AGL
- Low speed and high speed handling, controllability
    - Review flight results after each build-up before proceeding to next shape

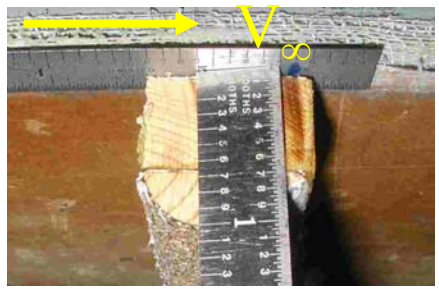
Sino Swearingen
AIRCRAFT CORPORATION

Natural Ice Validation

- **During the early 2005 testing, ice shape testing for the -3 and -4 configurations included:**
  - **Wing upper surface runback**
  - **Wing lower surface runback with a total height of ~0.7 inches (See Right)**
- **For the 2006 testing, ice shape testing for the -3 and -4 wing surface runback was modified based on natural ice test results.**
  - **Wing upper surface runback was eliminated.**
  - **Wing lower surface runback was increased to a total height of ~1.0 inches (See Below).**



2005



2006

Natural ice tests validated that we did not have upper surface runback

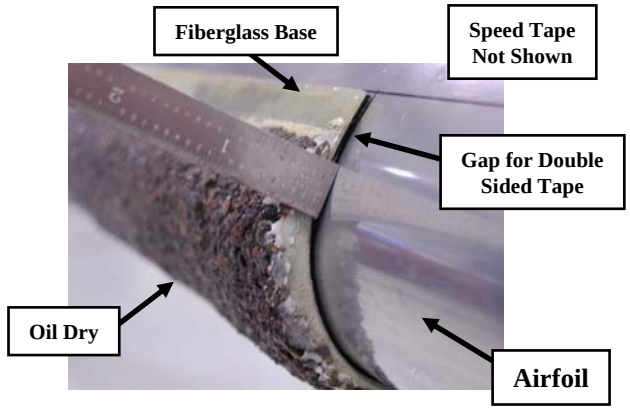
Natural Ice Validation

45 Minute Ice Shape

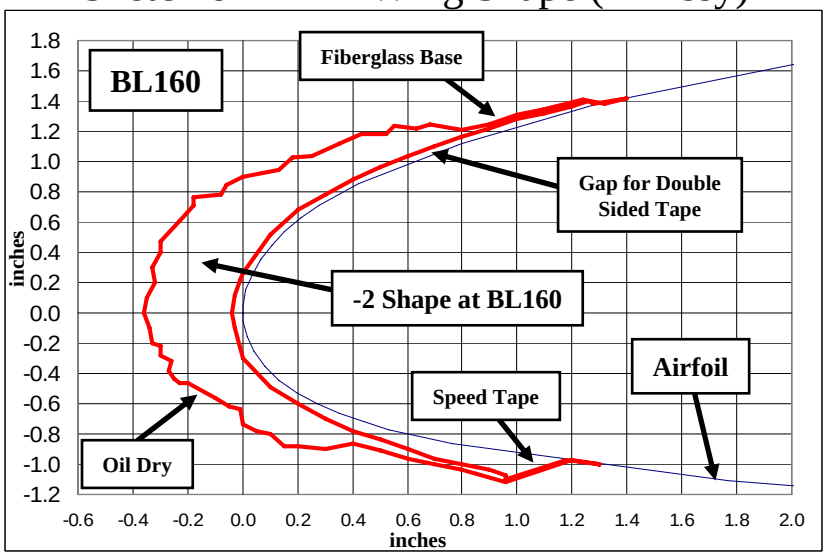
Remaining Ice after 50 minutes in maximum continuous icing and returning to land

Technical Issues

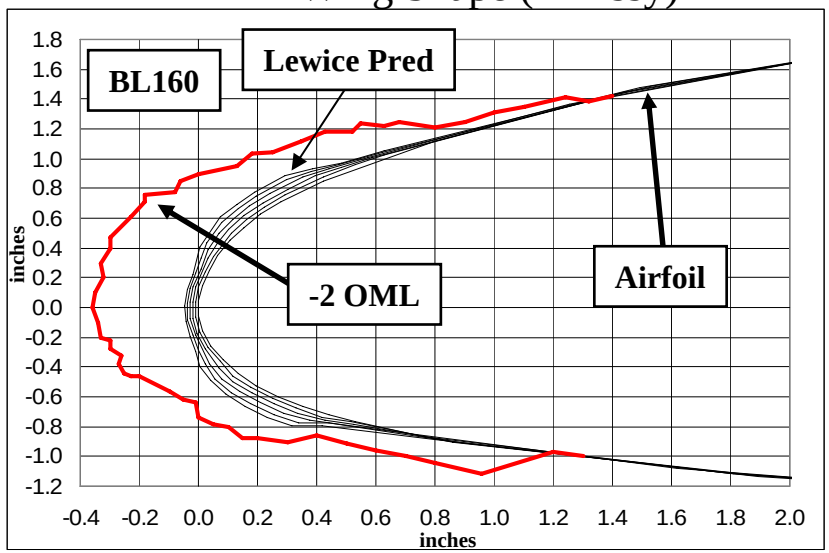
- **The -2 Assy is intended to reflect a shape consistent with the ice achieved during a 2 minute delayed activation encounter.**
- **However, due to thickness of the double sided tape, the fiberglass base, and the extra thickness of the oil dry, the shape flown is reflective of a shape at least 3 times larger than the shape predicted.**



Sketch of 2 Min Wing Shape (-2 Assy)



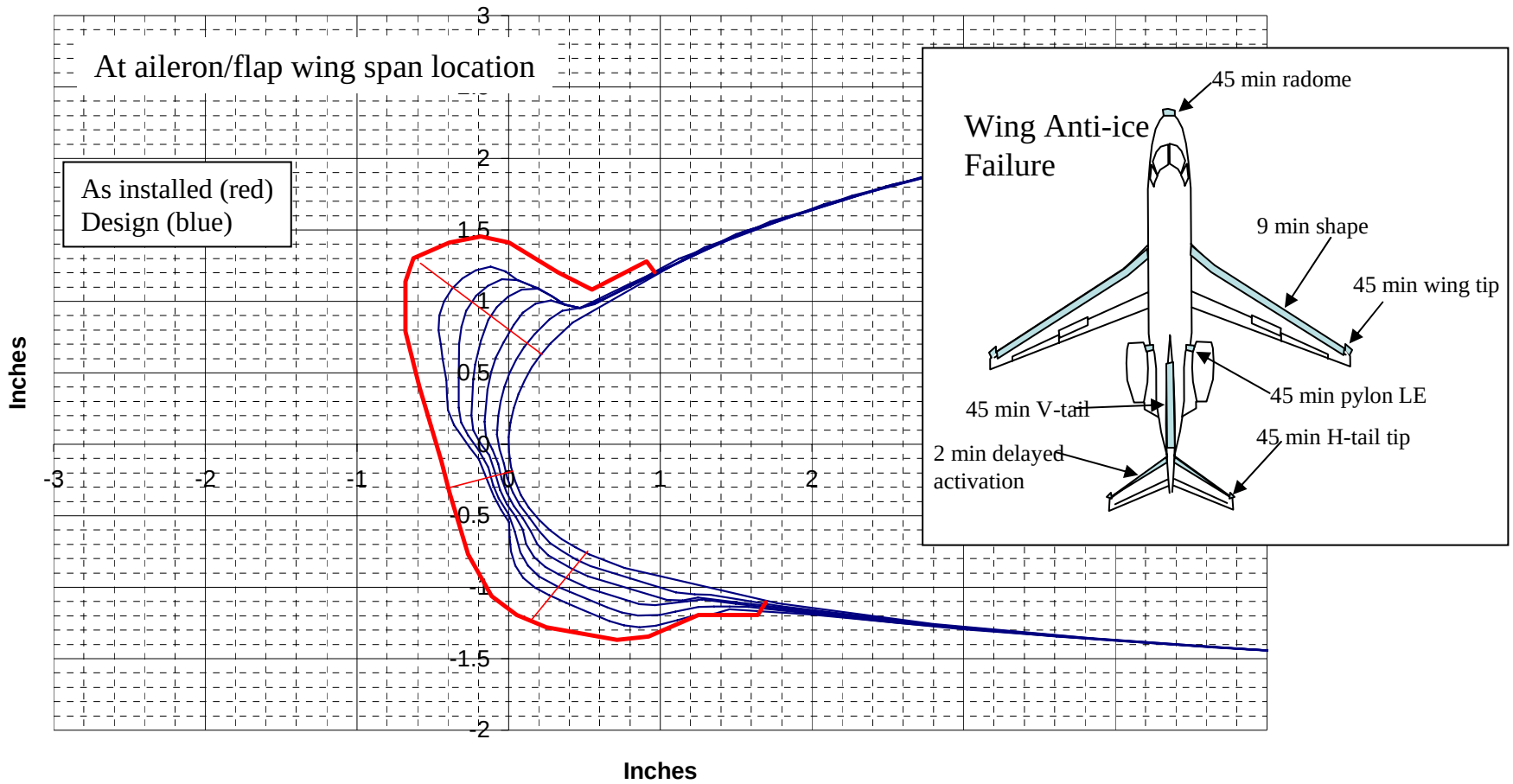
Comparison Against Predicted 2 Min Wing Shape (-2 Assy)



Technical Issues

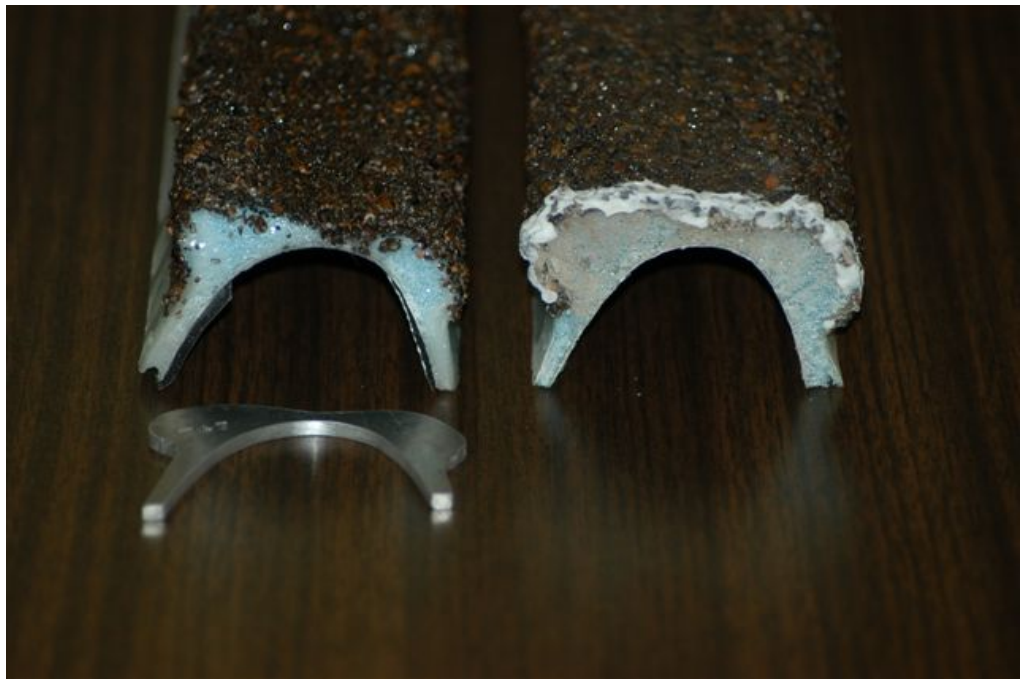
Wing Failure Ice as Installed vs Design

- The as installed shape, with the misfit due to the double sided tape and extra thickness of the oil dry, is approximately 25% larger than the minimum requirements, therefore representing about a 15 minute shape rather than a 9 min shape.

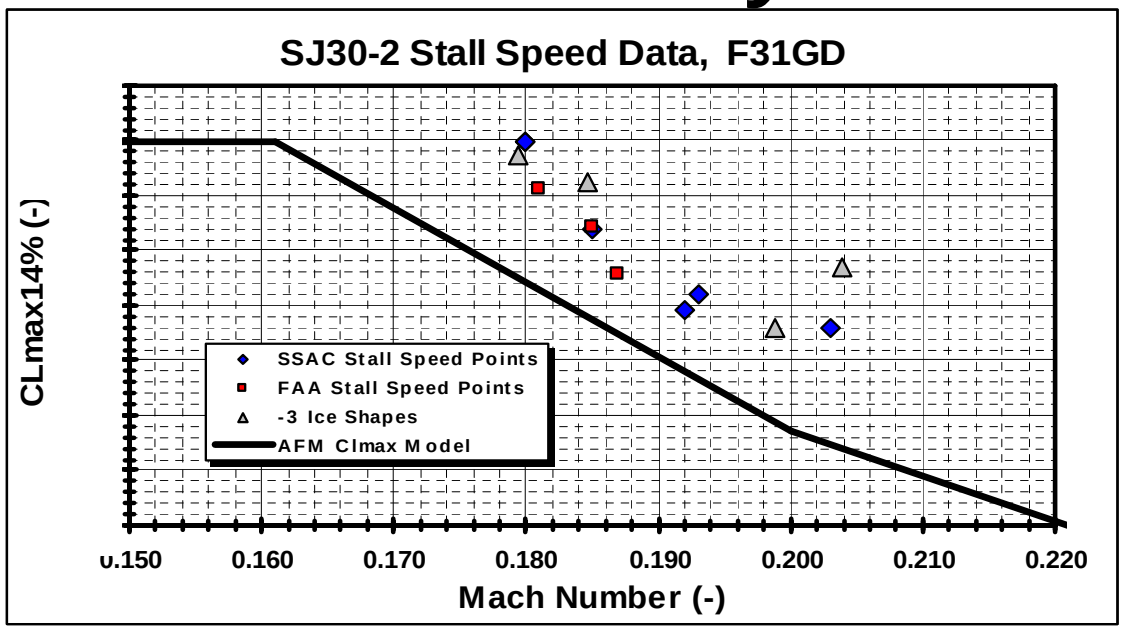


Technical Issues

Failure ice shapes re-built and validated with as installed templates.



Summary



- **For all conditions, stall warning was provided by the same means as the non-iced airplane (stick shaker), and maneuver margins were similar as non-iced airplane.**
- **For "normal ice/holding ice" stall speeds were unchanged.**
- **In addition, for pre-activation ice and failure ice, the stall warning margin is sufficient to allow the pilot to prevent stalling (reaching stall ID) when the pilot starts a recovery maneuver not less than 1 seconds after the onset of stall warning.**
  - **This is consistent with latest Part 25 NPRM (Nov 2005) on icing.**

Lessons Validated

Ice shapes testing is very high risk

1. Icing in the Eglin Climatic Chamber does not replicate reality
2. An icing tanker is valuable for system development
3. Develop a step by step plan
4. Do not short-cut the plan
5. Technical Review Boards
6. Safety Review Boards
7. Flight Readiness Review Boards
8. Practice safety procedures often